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(PROFESSIONAL PAPER.)

ALUM IN FOODS.

EXPLANATORY STATEMENT.

A report on the influence of aluminum compounds on the nutrition and health of man has been submitted by the Referee Board of Consulting Scientific Experts, in answer to questions put to it by the department. The report of the board itself, signed by each member, is brief, but it is accompanied by three elaborate reports giving the results of three sets of extensive experiments on human subjects conducted independently by three members of the board. To get the board's conclusions before the public at this time, it is considered advisable to publish its findings, but to omit the extensive reports of the three experimenters, giving only their final conclusions.

QUESTIONS SUBMITTED TO REFEREE BOARD.

The questions submitted to the board were as follows:

1. Do aluminum [1] compounds, when used in foods, affect injuriously the nutritive value of such foods or render them injurious to health?

2. Does a food to which aluminum compounds have been added contain any added poisonous or other added deleterious ingredient which may render the said food injurious to health? (*a*) In large quantities? (*b*) In small quantities?

3. If aluminum compounds be mixed or packed with a food, is the quality or strength of said food thereby reduced, lowered, or injuriously affected? (*a*) In large quantities? (*b*) In small quantities?

CHARACTER OF EXPERIMENTS CONDUCTED.

In order to base their report upon first-hand knowledge, the board instituted three sets of experiments, each independent of the others. One set of experiments was conducted by Dr. Russell H. Chittenden, of the Sheffield Scientific School, Yale University, New Haven; another by Dr. Alonzo E. Taylor, of the Medical School of the University of Pennsylvania, Philadelphia; and the third by Dr. John H. Long, of the Northwestern University Medical School, Chicago. In

[1] Aluminum is a synonym for aluminium, the metal used for cooking utensils and other implements. Alum or sodium aluminum sulphate is a salt of this metal.

each case tests were made on healthy young men by including aluminum in some form in their food. The food was all carefully measured and weighed and the amounts of its principal ingredients were determined by analysis. The excretions of the men's bodies (both urine and feces) were carefully collected, examined, and analyzed. Daily records of body weight, temperature, respiration, and pulse were kept for each man, and notes were made of any unusual symptoms. Any disturbance in health or physiological processes was thus detected.

Each experiment included three periods, in the first and last of which no aluminum was administered. During the middle period aluminum compounds were administered, the "dose" increasing as the experiment progressed. In this way the effect of large quantities was compared with that of small quantities. In Dr. Chittenden's and Dr. Taylor's experiments some of the men who served as "control" subjects received no aluminum at any time, so that any disturbances due to other causes might be checked up.

Dr. Chittenden's experiments included 12 men and continued from January 15 to June 22, 1912. During 130 days the diet contained bread raised with an alum baking powder made in the laboratory.[1] The dose of aluminum compound was increased from time to time, at first by increasing the quantity of bread and later by increasing the quantity of the baking powder used in making the bread. In this way the alum [2] used per man per day was increased from 0.578 gram [3] (8.920 grains) at the beginning to 2.287 grams [4] (35.295 grains) at the close of the dosage period; the actual aluminum contained in this dosage ranged from 0.065 gram (1.003 grains) to 0.257 gram (3.966 grains) per man per day. Eight men used the alum bread, while four had no aluminum in their food.

Dr. Long's experiments ran from February 8 to June 7, 1911, and included six men, all of whom received the dosage. Baking powder bread was not used, but instead for 40 days a mixture of the same composition as the residue left in such bread by alum baking powder was administered in the form of a powder in water or milk. For 30

[1] This bread was made fresh every day and contained in one baking of two loaves approximately:

Sifted flour	quarts	2
Baking powder (25 per cent calcined alum)	heaping teaspoonfuls	4
Salt (approximately one rounded teaspoonful)	ounce	½
Butter	do	1
Water, sufficient quantity.		

Later in the experiment a greater proportion of alum baking powder was used in the making of the bread in order to facilitate administering larger amounts of alum.

[2] The term "alum" as used under the heading "Character of experiments conducted" refers to the calcined sodic aluminic sulphate commonly used in alum baking powders and not to the ordinary crystallized alum.

[3] Equivalent to approximately two-thirds of a level teaspoonful of baking powder containing 25 per cent of alum. All the figures in this and succeeding footnotes must of necessity be approximate, since teaspoons vary in size and baking powders in composition.

[4] Approximately equivalent to 2⅔ level teaspoonfuls of alum baking powder.

days the quantity of alum used was 2 grams[1] (30.866 grains) a day for each man; in the next 10 days the dose was doubled. Afterwards for 30 days the baking powder residue was treated so as to wash out everything except the compounds of aluminum with hydrogen and oxygen (aluminum hydroxide), the dose at first being the amount obtained from 4 grams[2] (61.732 grains) of alum per man per day, which was increased in the second 10 days to 6 grams[3] (92.598 grains) and in the third 10 days to 10 grams (154.330 grains) of alum. Finally, in a period of 10 days, the dose was the sodium sulphate consumed when 4 grams of alum were used, this compound being the cathartic ingredient which is left in bread by alum baking powder.[4]

Dr. Taylor conducted experiments with a squad of eight men from October 8, 1911, to May 10, 1912, with an intermission from December 16 to January 14. In this case also the powder was not used in bread, but was administered in wafers or dissolved in water. Six of the subjects took the aluminum compounds, while the other two took milk sugar, the men themselves not knowing which they were taking. There were two groups of experiments in which the whole squad took part. In the experiments of the first group, which ran from October 8 to December 16, tests were made with alum alone. The dose at first was such as to give each man 0.1 gram[5] (1.5433 grains) of aluminum a day and was increased from time to time until the daily dose was 0.298 gram[6] (4.599 grains) of aluminum for each man. The second group ran from January 14 to May 10. Tests were made with the residue from alum baking powder; tests were also made with certain aluminum compounds (aluminum hydroxide and aluminum chloride) which may be found in the residues from alum baking powders of different kinds, and with sodium sulphate, the purgative salt left in bread by alum baking powders. The smallest dose of the compounds containing aluminum gave each man 0.227 gram[7] (3.503 grains) of aluminum a day, while the largest dose gave 0.969 gram[8] (14.954 grains) of aluminum a day. The dose of the purgative salt (sodium sulphate), in which there is no aluminum,

[1] Approximately equivalent to 2⅔ level teaspoonfuls of alum baking powder. Equivalent to about 0.223 gram (3.44 grains) of aluminum.

[2] Approximately equivalent to 4½ level teaspoonfuls of alum baking powder.

[3] Approximately equivalent to 6⅝ level teaspoonfuls of alum baking powder. These amounts of alum are equivalent to about 0.44 gram (6.86 grains), 0.67 gram (10.29 grains), and 1.11 grams (17.15 grains) of aluminum.

[4] Editorial note: Sodium sulphate or Glauber's salt is a substance derived from the interaction of alum and baking soda in making bread with alum baking powders and is of itself a cathartic, formerly much used medicinally. Cream of tartar baking powder, when used in bread, by a similar interaction produces a cathartic substance known as sodium tartrate. Phosphate baking powders when used in making bread produce a cathartic substance known as sodium phosphate. Cream of tartar and phosphate baking powders produce catharsis, similar to that produced by alum baking powders, when used in quantities.

[5] Approximately equivalent to a level teaspoonful of alum baking powder.

[6] Approximately equivalent to 3 level teaspoonfuls of alum baking powder.

[7] Approximately equivalent to 2½ level teaspoonfuls of alum baking powder.

[8] Approximately equivalent to 10 level teaspoonfuls of alum baking powder.

was 5.23 grams [1] (80.714 grains) per man per day. Following these experiments four men took 1 gram (15.433 grains) of aluminum a day each for several days,[2] and then their blood was tested to detect any aluminum that might be present in it. No aluminum was found in the blood. As a further indirect test to determine whether aluminum was resorbed, one man took for five days enough aluminum hydroxide to furnish 0.660 gram (10.186 grains) of aluminum a day and another took enough to give 0.540 gram (8.334 grains) a day for five days. The men were fed a diet of low and known phosphorus content and the excrementa analyzed for phosphorus, in order to detect, if possible, signs of abstraction of this element from the tissues by resorbed aluminum. This test failed to demonstrate resorption of aluminum.

CONCLUSIONS OF INDIVIDUAL INVESTIGATORS.

Dr. Chittenden concludes from his experiments that small quantities of aluminum compounds, and even comparatively large quantities, when taken daily with the food, have no effect upon the general health and nutrition of the body. "In other words," as he sums up his conclusions, "aluminum compounds when used in foods—as in bread—in such quantities as were employed in our experiments do not affect injuriously the nutritive value of such foods or render them injurious to health, so far as any evidence obtained in our experimental work indicates."

Dr. Long, in concluding his report, calls attention to the fact that alum is rather generally used in the manufacture of cucumber pickles. This is an old practice which had its origin in the household rather than in the factory and is still common in the household. The hardening effect of the alum is believed to help in keeping the pickles. In the factory the cucumbers are first soaked for several weeks in strong brine, then in fresh water overnight, this process being sometimes repeated. Then the cucumbers are put into an alum liquor in which the weight of alum used is about one-fourth of 1 per cent of the weight of the cucumbers. The cucumbers and liquor are heated up to 120° or 140° F., then cooled and allowed to stand for from 6 to 24 hours. Then comes a bath in fresh water and afterwards the final treatment with vinegar. The vinegar takes out some of the alum from the pickles, so that usually the alum left in them amounts to less than two-tenths of 1 per cent.

Alum is also used in the preparation of maraschino cherries, and perhaps some other fruits. But the quantities of aluminum that might be consumed either in pickles or in the fruits referred to are so small, compared with the quantities actually consumed in baking powders, that the study of alum baking powders may be taken to cover the entire field.

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[1] About one-fifth ounce of Glauber's salt. (See footnote, p. 3.)

[2] This corresponds to approximately 10 level teaspoonfuls of alum baking powder.

Alum, as such, is not present in the food when eaten. In the process of baking, the alum and soda in baking powder break up and recombine into several compounds. One product is the carbonic acid gas, which does the work of leavening. This gas passes off, leaving in the bread an aluminum compound and a compound called sodium sulphate. Dr. Long concludes that the cathartic action of large residues from the alum and soda combination—for instance, the residue left when the large dose of alum, 4 grams [1] (61.732 grains), was used—must be considered objectionable when administered daily. But this is much above the consumption in actual practice, and amounts of alum not above 2 grams [2] (30.866 grains) a day—a liberal allowance—do not appear to be harmful in any practical sense. Since the quantities of aluminum compounds consumed with other foods are insignificant compared with the quantities consumed in foods prepared with baking powder, the findings from the study of baking powder residues must be held to cover all cases. Keeping in mind that the aluminum compounds actually in the food when consumed are comparatively inert, Dr. Long declares that "it can not be said that, when mixed with foods in the small quantities actually considered necessary, they add a poisonous or deleterious substance, or injuriously affect the quality of the food with which they are used."

Dr. Taylor's conclusions agree in effect with those of his associates. He says, "We have had, unquestionably, evidences of the catharsis caused by the administration of large doses of baking powder." With the large doses used in his experiments, the stools are increased in weight and frequency, the movements are loose, and colic is apt to attend the evacuations. This condition is the result of sodium sulphate, which, though not an aluminum compound, is a residue of the alum baking powder. But with very large doses of aluminum compounds occasional dry colic may also be noted.

"I personally," says Dr. Taylor, "do not believe that it would be healthful for anyone, in camp or out of camp, to live upon a diet of baking powder biscuits. I do not believe that the regular ingestion of sodium sulphate in doses of from 3.5 to 5 grams [3] (54 to 77 grains) per day, with the normal diet, resulting in distinct looseness of the bowels, is a procedure to be recommended. Prolonged administration of saline cathartics even in small dose tends to leave behind a condition of constipation; and it is certainly the experience of the medical profession that the practice of the regular administration of saline cathartics is not to be recommended. This aspect of the question is of course not peculiar to aluminum baking powder, but applies to all baking powders, since to a greater or less extent a saline cathartic remains as the residue of the reactions of all known baking powders,

[1] Approximately equivalent to 4½ level teaspoonfuls of alum baking powder.
[2] Approximately equivalent to 2¼ level teaspoonfuls of alum baking powder.
[3] One-eighth to one-sixth ounce of Glauber's salt.

as demonstrated in direct tests with different baking powders on human subjects.[1] There is no evidence in our results to indicate that the occasional and ordinary use of bread, biscuits, or cake prepared with aluminum baking powder tends to injure the digestion. The amount of saline cathartic that would be ingested under conditions of normal diet would be very small and would provoke no catharsis or symptoms of any kind."

One other effect of the administration of compounds of aluminum is noted by Dr. Taylor, namely, a distinct decrease of phosphates in the urine and a corresponding increase of phosphates in the stools. But the extent of this change is too slight for it to have any material meaning or effect.

CONCLUSIONS OF THE REFEREE BOARD.

With the results of these independent experiments agreeing so well, the Referee Board were enabled to draw up a unanimous report, signed by all the members, namely: Ira Remsen, president of Johns Hopkins University, chairman; Russell H. Chittenden, professor of physiological chemistry in Yale University and director of the Sheffield Scientific School; John H. Long, professor of chemistry in the Northwestern University Medical School; Alonzo E. Taylor, Benjamin Rush professor of physiological chemistry in the University of Pennsylvania; and Theobald Smith, professor of comparative pathology in Harvard University.

In their report the board first define their understanding of the terms "small quantity" and "large quantity," as applied to alum baking powders, as follows:

> By the term "small quantity" we understand such an amount as may be ingested in the normal use of biscuits, pastry, or other articles leavened with baking powder, as these foods are practically used in the ordinary American family. This amount will not average more than 25 to 75 milligrams [2] (0.39 to 1.16 grains) of aluminum daily for the days of consumption of such articles.

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[1] "We must not, however, be oblivious to the fact," says Dr. Taylor, who conducted part of these investigations, "that a saline cathartic residue results from the reaction of every form of known baking powder now commonly employed. The use of cream of tartar or tartaric acid baking powder leaves in the alimentary tract a residue of tartrates which exhibit the action of a saline cathartic and of diuresis [excessive excretion of urine] as well. The so-called phosphate baking powder leaves as a residue of reaction sodium phosphate, again a saline cathartic. And aluminum baking powder leaves as a residue of reaction sodium sulphate, a saline cathartic. Apparently therefore, at present at least, the use of baking powder is associated with the introduction into the alimentary tract of a certain amount of saline cathartic, the salt differing with the use of the particular type of baking powder."

[2] This is approximately equivalent to one-quarter to three-quarters of a level teaspoonful of alum baking powder.

By the term "large quantity" we understand such an amount of aluminum as would be ingested only under very unusual conditions, as for example, where the flour consumption is mainly in the form of biscuits or other articles leavened with aluminum baking powders. This amount may reach 150 to 200 milligrams [1] (2.31 to 3.09 grains) of aluminum per day. A person subsisting mainly on baking-powder biscuits, as may happen in camp life, might ingest an amount in excess of 200 milligrams per day. With this possibility in mind, we have also studied the effects of amounts up to and exceeding 1,000 milligrams [2] (15.4 grains) of aluminum per day.

With this understanding of the terms, the board give the following answers to the questions submitted to them:

Aluminum compounds when used in the form of baking powders in foods have not been found to affect injuriously the nutritive value of such foods.

Aluminum compounds when added to foods in the form of baking powders, in small quantities, have not been found to contribute any poisonous or other deleterious effect which may render the said food injurious to health. The same holds true for the amount of aluminum which may be included in the ordinary consumption of aluminum baking powders furnishing up to 150 milligrams (2.31 grains) of aluminum daily.

Aluminum compounds when added to foods, in the form of baking powders, in large quantities, up to 200 milligrams (3.09 grains) or more per day, may provoke mild catharsis.

Very large quantities of aluminum taken with foods in the form of baking powders usually provoke catharsis. This action of aluminum baking powders is due to the sodium sulphate which results from the reaction.

The aluminum itself has not been found to exert any deleterious action injurious to health, beyond the production of occasional colic when very large amounts have been ingested.

When aluminum compounds are mixed or packed with a food, the quality or strength of said food has not been found to be thereby reduced, lowered, or injuriously affected.

In short, the board conclude that alum baking powders are no more harmful than any other baking powders, but that it is wise to be moderate in the use of foods that are leavened with baking powder.[3]

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[1] This is approximately equivalent to 1½ to 2 level teaspoonfuls alum baking powder.

[2] Approximately equivalent to 10 level teaspoonfuls alum baking powder.

[3] See footnotes, pages 3 and 6.

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